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(54) Diffusion-bonded sputtering target assembly and method of manufacturing the same.

(57) A sputtering target assembly comprising a sputtering target and a backing plate characterized in that said sputtering target and backing plate is diffusion-bonded with or without an insert or inserts interposed there-between so as to have solid phase diffusion-bonded interfaces, said diffusion-bonded ~~sputtering target substantially maintaining metallurgical characteristic and properties of the sputtering~~ target before it is diffusion-bonded to said backing plate. The solid-diffusion bonding of the target and backing plate, with or without one or more insert interposed therebetween, at a low temperature and pressure, causes interdiffusion of their constituent atoms to attain high adhesion and bond strength without attendant deterioration or large deformation of the target material, while inhibiting the crystal growth in the target material. The bond thus obtained proves highly reliable because it undergoes no abrupt decrease in bond strength upon elevation of their service temperature and owing to the solid phase bonding, 100% bonding is achieved with noun-bonded portions such as pores left along the interfaces.

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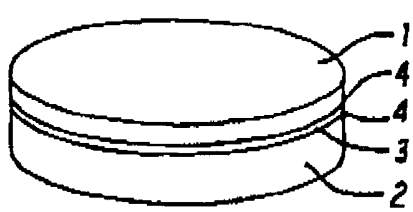

FIG. 1

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[Field of the invention]

This invention relates to a sputtering target assembly composed of a sputtering target and a backing plate, and more specifically to a sputtering target assembly and a method of manufacturing the same featuring by bonding a sputtering target and a backing plate by solid-phase diffusion bonding, with or without an insert or inserts placed therebetween.

By solid-phase diffusion bonding, a sputtering target exhibits excellent adhesion and bond strength to a backing plate while maintaining its structure and crystal characteristics including crystal gain size, crystal orientation etc. which it had before the diffusion bonding with no contamination possibly caused by the bonding process.

[Background of the Invention]

Sputtering targets serve as sputtering sources to form electrodes, gates, wirings, elements, protective films and the like of various semiconductor devices on substrates by sputtering operation. They usually take the form of disk-shaped plates. As accelerated particles impinge against a target surface, part of the atoms constituting the target is sputtered to the space by momentum exchange to deposit on an oppositely located substrate. Typical sputtering targets in use include Al and Al alloy targets, a refractory metal and its alloy (W, Mo, Ti, Ta, Zr, Nb, etc. and their alloys such as W-Ti) targets, and high-melting silicide ($MoSi_x$, WSi_x, etc.) targets. The targets are usually used in the form of assembly integrally bonded with a backing material, known as a backing plate, which provides both support and cooling functions. A sputtering target assembly is mounted in a sputtering system, and the rear side of the backing plate is cooled to dissipate the heat that is generated in the target during sputtering operation. The backing plates in use today are made of metals and alloys with good thermal conductivities, such as oxygen-free copper (OFC), Cu alloys, Al alloys, stainless steels (SUS), and Ti and Ti alloys.

Heretofore, for the bonding of a sputtering target and a backing plate to constitute a sputtering target assembly, brazing method using a low-melting brazing material such as In or Sn alloy has been primarily employed. But, the brazing technique using a low-melting brazing material has the following disadvantages:

(1) The low melting point of brazing materials, 156 °C for In or 160-300 °C even for an Sn alloy, causes a sharp drop of the bond strength under shear as the service temperatures approaches its melting point. Specifically, the bond strength under shear at room temperature is less than 1 kg/mm² for In and 2-4 kg/mm² for even an Sn alloy which has relatively high strength. This combines with the low melting point of the brazing material to cause a sharp drop of the bond strength under shear upon temperature rise.

(2) With the brazing technique, 100% bonding with no un-bonded portions is difficult to achieve since the contraction upon solidification of the brazing material during the bonding process leaves pores (air gaps) behind along the bonded interfaces between the target and backing plate.

Consequently, the electric power to be provided for sputtering is limited to a low level. Also, when the system is loaded with greater sputtering power than specified or operated under inadequate cooling water control, troubles such as the separation of the target are caused due to a decrease in bond strength upon temperature rise of the target or melting of the brazing material.

The employment of a high-melting brazing material in place of the low-melting one requires a higher temperature for brazing, which sometimes affects the target quality adversely.

A recent tendency is toward the use of greater electric power for sputtering to improve the throughput for film forming by sputtering. In view of this, there is strong demand for a target which is capable of maintaining the bond strength above a predetermined level even at elevated temperatures.

Meanwhile, Japanese Patent Application Public Disclosure Nos. 143268/1992 and 143269/1992 disclosed targets and methods of manufacturing them which involve a process of integrally bonding a first metal member that serves as a sputtering material to a second metal member that serves as a support either directly or through the interposition of a spacer having a higher melting point than the first metal member. As regards the method of integrally bonding them together, explosive welding is primarily explained. Others referred to as employable are hot press, HIP, and hot roll methods. Taking the hot press method for example, it is described as comprising the steps of working and machining, e.g., an al-1%Si alloy as the first metal member (sputtering material) and oxygen-free copper as the second metal member (support), both to relatively simple shapes, and bonding the two members by hot pressing at 300-500° C for 60 minutes, whereby a diffusion layer of about 2 µm thickness is said to be formed, and thereafter machining the first and second metal members (sputtering material and support) thus bonded together to final configurations. It is also stated to the effect that alternatively the first and second metal members having been machined to desired shapes may be bonded by explosive welding.

[Problems to be solved]

The methods described above involve high pressure bonding of the first and second metal members

under very great impact or heavy load such as a explosive bonding, hot press, HIP, or hot roll technique. This process causes serious deformation of the first metal member to be sputtered (target material), and attendant increased internal strains and the change of crystal structure.

Particularly, the uniformity as of crystal size and crystal orientation of a target is destroyed resulting in different crystal grain diameters and crystal orientations on various locations of the target. As a result, the quantity of sputter from the target begins to vary from point to point which leads to variation of deposited film thickness and hence deposited film properties. This problem is recently pointed out that this is a matter of serious concern. Further, the contamination of surface layer of the target produced is severe and so the yield of target material to be finished to the final size is very poor. Although it is also stated in the above mentioned publication that the first and second metal members may be bonded by explosive bonding after they have been machined to desired configurations, in that case, deformation of the target material and attendant increased internal strains and the change of crystal structure, and surface layer contamination are inevitable as stated above.

Recently, target materials having melting points below 1000° C, e.g., aluminum or aluminum alloys, have rapidly come into use for the wirings or interconnections of semiconductor devices. These target materials in many cases are supplied as finished to final geometry with very high purity. Such relatively lower melting target materials are susceptible to larger damages of its crystal structure, sometimes accompanied with coarsening of grain size of the target material.

[Object of the Invention]

The present invention has for its object the development of a technique for bonding a target material finished to the final geometry or near net shape of the final geometry to a backing plate with a high strength while maintaining the uniformity of the crystal structure and imparting no deformative, degrading, or other unfavorable effect upon the target material itself.

[Summary of the invention]

The present inventors have searched for a bonding method for target materials which inhibits the crystal characteristics such as crystal grain growth and causes little deformative or other adverse effects upon the material. As a result, it has now been found that solid-phase diffusion bonding with or without the use of an insert produces a far better bond than expected in their interfaces. The diffusion bonding, performed while maintaining a solid phase under a light load (a low strain rate) in a vacuum, gives high adhesion and high bond strength with no or very small deformation of the target material and with no un-bonded portions such as pores along the interfaces, while inhibiting the destruction of uniform crystal structure, the growth of grains, etc. which the target material had before the bonding.

The term "solid-phase diffusion bonding" as used herein means a technique of bonding a target material and a backing plate with or without an insert or inserts sandwiched therebetween by diffusion along the interfaces under light heating and pressing conditions, whereby the two members are bonded while maintaining the solid phase rather than being melted, without causing unfavorable effects upon the target material including its grain growth and structure change.

Based upon this discovery, this invention provides a sputtering target assembly comprising a sputtering target and a backing plate characterized in that said sputtering target and backing plate are solid-phase diffusion-bonded with or without an insert or inserts interposed therebetween so as to have solid phase diffusion-bonded interfaces therebetween, said diffusion-bonded sputtering target substantially maintaining metallurgical characteristics and properties that the sputtering target had before it is diffusion-bonded to said backing plate.

It is convenient in explanation to divide target materials into ones having melting temperatures below and no less than 1000 °C and separately discuss them.

This invention, in its first aspect, provides:

(1-1) a solid-phase diffusion-bonded sputtering target assembly characterized by being composed of a target material having a melting point below 1000° C, one or more insert, and a backing plate, said target material, said insert and said backing plate having solid-phase diffusion bonded interfaces formed therebetween, said target material having uniform crystal structural with a grain size not exceeding 250 µm; and

(1-2) a method of manufacturing a sputtering target assembly, said target material having a grain size not exceeding 250 µm characterized by solid-phase diffusion bonding of a target material of a given final shape having a melting point below 1000 °C and a backing plate of a given final shape, with one or more inserts interposed therebetween, under a vacuum at a temperature between 150 and 300 °C.

Typical of the target material consists of aluminum or an aluminum alloy. The insert typically consists of silver or a silver alloy, copper or copper alloy, or nickel or a nickel alloy.

This invention, in a second aspect, provides:

(2-1) a solid-phase diffusion-bonded sputtering target assembly characterized by being composed of a target material having a melting point

no less than 1000 °C, one or more insert selected from the group consisting of metals or alloys having lower melting points than the target material, and a backing plate, said target material, said insert and said backing plate having a solid-phase diffusion bonded interfaces formed therebetween; and

(2-2) a method of manufacturing a sputtering target assembly characterized by solid-phase diffusion bonding of a target material of a given final shape having a melting point no less than 1000 °C and a backing plate of a given final shape, with one or more insert interposed therebetween, said insert being made of one or more materials selected from the group consisting of metals or alloys having lower melting points than the target material, under a vacuum at a temperature between 200 and 600 °C and at a pressure between 0.1 and 20 kg/mm².

The target material typically includes a refractory metal selected from the group consisting of W, Mo, Ti, Ta, Zr and Nb and its alloys. The insert typically consists of silver or silver alloys, copper or copper alloys, or nickel or nickel alloys.

In a combination of a titanium target material and a titanium backing plate, we have found that the solid-phase diffusion bonded is permitted with no use of insert.

Then, in a third aspect, this invention provides:

(3-1) a solid-phase diffusion-bonded sputtering target assembly characterized by being composed of a titanium target material and a backing plate of titanium, which have solid-phase diffusion bonding interfaces formed therebetween, said target material having a uniform crystal structure with a crystal grain diameter not exceeding 100 μm; and

(3-2) a method of manufacturing a solid-phase diffusion bonded sputtering target assembly in which the target material has a uniform crystal structure with a crystal grain diameter of not exceeding 100 μm, characterized by solid-phase diffusion bonding of a titanium target material and a backing plate of titanium under conditions such that the strain rate attained is at most 1×10^{-4}/sec., preferably at 350-650 °C.

The solid-phase diffusion bonding of the target and backing plate, with or without one or more insert sandwiched therebetween, at a low temperature and pressure causes interdiffusion of their constituent atoms to attain high adhesion and bond strength without attendant deterioration or deformation of the target material, while inhibiting the crystal grain growth in the target material. The bond thus obtained proves highly reliable because it undergoes no abrupt decrease in bond strength upon elevation of the service temperature and, owing to the solid phase bonding, 100% bonding is achieved with no un-bonded portions such as pores left along the interfaces.

[BRIEF EXPLANATION OF THE DRAWINGS]

FIG. 1 is a perspective view of a sputtering target assembly consisting of a target material and a backing plate bonded through an insert by solid-phase diffusion bonding in accordance with this invention.

FIG. 2 is a graph comparing the bond strength values under shear at room temperature of the diffusion-bonded target assembly of this invention with those of the bonded material that used a low-melting brazing material of the Sn-Pb-Ag system in Example 1.

FIG. 3 is a graph showing the temperature dependence of the bond strength values under shear of the bonded materials of Example 1.

FIG. 4 is a micrograph showing the metallographic structure in the vicinity of bonded interfaces of an assembly consisting of an Al-1%Si-0.5%Cu target, Ag foil, and an OFC backing plate according to this invention.

FIG. 5 is a micrograph showing the metallographic structure in the vicinity of bonded interfaces of an assembly consisting of a tungsten target and a titanium backing place bonded with an insert by solid-phase diffusion bonding.

FIG. 6 is a graph comparing the bond strength values under shear at room temperature of the solid-phase diffusion-bonded target assembly of this invention with those of the assembly that used an In brazing metal in Example 6.

FIG. 7 is a micrograph showing the metallographic structure in the vicinity of the bond interface of an target assembly consisting of a titanium target solid-phase diffusion-bonded to a backing plate of titanium.

[Explanation of preferred embodiments]

There is shown in FIG. 1 a diffusion-bonded sputtering target assembly manufactured by diffusion-bonding a target material 1 and a backing plate 2 through an insert 3 in accordance with this invention. The components are solidly bonded together with solid-phase diffusion-bonded interfaces 4. The insert 3 may be omitted depending upon a combination of the target material and the backing plate. In this case, the target material 1 and the backing plate 2 directly form their solid-phase diffusion-bonded interface. The target material maintains the metallurgical characteristics and properties that it had before diffusion bonding.

The objective of this invention includes many kinds of target materials. For convenience in explanation, an explanation will be made dividing target materials with the melting point of 1000 °C as a measure. This invention includes, as its objective, both target materials having melting points of no more than 1000

°C and target materials having melting points of beyond 1000°C.

Typical examples of target materials having a melting point no more than 1000 °C are aluminum and aluminum alloys such as Al-Si-Cu, Al-Si, and Al-Cu alloys. Other alloy targets composed principally of such metals as Cu or Au also come within the contemplation of this group. As for insert materials, Ag, Cu, Ni, or their alloys are usually used. One or more such insert materials may be used in layers.

Examples of target materials having a melting point above 1000°C are target materials of refractory metals and their alloys, such as W, Mo, Ti, Ta, Zr, Nb, and W-Ti, and of high-melting compounds, such as high-melting silicides ($MoSi_2$, WSi_2, etc.). The material to be used as an insert herein is one or more of metals or alloys having a melting point lower than that of the target material. Typical of insert materials is Ag, Cu, Ni, or their alloy. For solid-phase diffusion bonding, the use of an insert material having a lower melting point than the target material employed is essential.

In the combination of a titanium target material and a titanium backing plate, the solid-phase diffusion-bonding is permitted with no use of an insert. As the titanium target materials, high-purity titanium target materials having a purity of 99.99% or upward are preferable. Titanium backing plates may be of ordinary industrial purity. For the purposes of the invention the term "titanium" is used to encompass the alloys with small percentages, up to 10% by weight, of alloying additives, such as Al, V, and Sn.

In fabricating a sputtering target assembly with the use of insert(s), a backing plate and a target material are degreased and rinsed with an organic solvent like acetone. Then, between the two is interposed an insert of one or more materials chosen from among Ag, Cu, Ni, and their alloys, desirably having at least 10μm thickness. The insert too must be degreased and rinsed beforehand. The use of a 10 μm or thicker insert is desirable because the micropores that result from surface irregularities, on the order of several micrometers, caused by machining of the surfaces of the target and backing plate to be bonded, would otherwise lessen the adhesive strength. The upper limit of thickness of the insert is not specified provided the insert is thick enough for solid-phase diffusion bonding. Excessive thickness is wasteful, however. A conventional foil, thin sheet or the like may be employed. For the material of the insert, Ag, Cu, Ni, or their alloy is suitable as referred to above, by reason of moderately high melting point and diffusionability to permit solid phase diffusion bonding. The insert is not limited to a single layer. Two or more superposed layers may be used instead. The surfaces to be bonded should be free from oxides or other impurities.

In the case of a target materials having a melting temperature no more than 1000 °C, a laminate consisting of a target material, a backing plate, and an insert is generally diffusion-bonded in a solid state by holding it at a constant temperature within a bonding temperature range of 150-300°C, preferably of 150-250 °C, under a vacuum of 0.1 Torr or below and at a pressure of 1.0-20 kg/mm², preferably 3-10 kg/cm². In this way a sputtering target assembly is obtained. To avoid the formation of oxides, the bonding desirably is carried out in a vacuum atmosphere of 0.1 Torr or below. The choice of load to be applied depends upon the bonding temperature and the materials to be used. For sufficient pressure bonding to produce interfacial diffusion, the load must be at least 1.0 kg/mm². On the other hand, a load in excess of 20 kg/mm² can damage the target material. The bonding temperature is set within 150-300 °C for the following reasons. If it is below 150 °C insufficient diffusion of atoms results in poor adhesion. If it exceeds 300 °C crystal grain growth takes place in the target material. Moreover, because of the difference in thermal expansion rate, the target material and backing plate tend to warp or distort, leading to inadequate bonding.

In the case of target materials having melting points more than 1000° C, a laminate consisting of a target material, a backing plate, and an insert is generally diffusion-bonded in a solid state by holding it at a constant temperature within a bonding temperature range of 200-600 °C under a vacuum of 0.1 Torr or below and at a pressure of 0.1-20 kg/mm², preferably 3-10 kg/mm². In this way a sputtering target assembly is obtained. It is to avoid the formation of oxides that the bonding is carried out in a vacuum atmosphere of 0.1 Torr or below. The choice of the applicable load depends on the bonding temperature and the materials to be used. For sufficient pressure bonding to produce interfacial diffusion, the load must be at least 0.1 kg/mm². On the other hand, a load in excess of 20 kg/mm² can damage the target material. The bonding temperature is set within 200-600 °C for the following reasons. If it is below 200 °C insufficient diffusion of atoms results in poor adhesion. If it exceeds 600 °C the crystal structure, mechanical properties and the like of the target material and/or backing plate can deteriorate. Moreover, because of the difference in thermal expansion rate, the target material and backing plate tend to warp or distort, leading to inadequate bonding.

In the case where a titanium target material and a titanium backing plate are used, a laminate consisting of a target material and a backing plate is generally diffusion-bonded in a solid state by holding it at a constant temperature within a bonding temperature range of 350-650 °C, preferably of 450-600 °C, under a vacuum of 0.1 Torr or below and a load of 0.1-20 kg/mm², at a strain rate of 1×10^{-3} /sec or below, preferably 1×10^{-4} / sec or below. In this way a sputtering target assembly is obtained. To avoid the formation of oxides, the bonding desirably is carried out in a va-

cuum atmosphere of 0.1 Torr or below. The choice of applicable load depends on the bonding temperature and the materials to be used. For sufficient pressure bonding to produce interfacial diffusion, the load must be at least 0.1 kg/mm². On the other hand, a load in excess of 20 kg/mm² can damage the target material. The bonding temperature is set desirably within the range of 350-650 °C for the following reasons. If it is below 350°C insufficient diffusion of atoms results in poor adhesion. If it exceeds 650°C grain growth tends to occur in the target material. Controlling the strain rate is particularly important. A strain rate in excess of 1×10^{-3} /sec would cause non-uniform straining inside the target and attendant partial structural changes. It could also result in a decrease in the bond strength at and along the diffusion bonding interface.

The sputtering target assembly thus obtained shows no deterioration of the target material, has bonded interfaces with a bonding area percentage of 100% produced by liquid phase-free solid phase diffusion bonding, and can satisfactorily be used even in a high-power sputtering system. In addition, the crystal grain size of the target material can be kept below a required standard, for example no more than 250 µm even for target materials having melting points of no more than 1000°C and no more than 100µm for an assembly of titanium target material and titanium backing plate, and uniform sputtering can be ensured. To reduce the adsorbed water, gas and the like on the target surface, it is possible to bake the target itself at about 200 °C before use unlike the case where a low-melting brazing filler metal is used.

Further explanations will be made with the Examples. The Examples set forth herein are merely for illustration and do not intend the restriction of this invention.

(Example 1)

An Al-1%Si-0.5% Cu target material in the form of a disk 300 mm in diameter and an oxygen-free copper (OFC) backing plate of the same size were ultrasonically degreased and rinsed with acetone. An insert of Ag foil 100 µ m thick was used. The insert, after the ultrasonic degreasing and rinsing with acetone, was sandwiched between the Al-1%Si-0.5%Cu target material and the OFC backing plate.

The laminate consisting of the Al-1%Si-0.5%Cu target material, Ag foil insert, and OFC backing plate was diffusion-bonded in a vacuum of 5×10^{-5} Torr, at a bonding temperature of 250 °C and under a load of 8 kg/mm². The grain size of the target after the bonding was 150 µm.

Solid-phase diffusion bonding was performed similarly but changing the bonding temperature alone to 350 °C. The grain size was now 400µm.

The bond strength values under shear at room temperature of test pieces cut out of five different diametral points of the diffusion-bonded material are compared, in FIG. 2, with those of corresponding test pieces of a laminate consisting of the same Al-1%Si-0.5%Cu target material and OFC backing plate similarly bonded but with an ordinary low-melting brazing material of the Sn-Pb-Ag system. FIG. 3 shows the temperature dependence of the bond strength values under shear of these bonded materials. As is obvious from FIGs. 2 and 3, the bond strength under shear of the laminate using the Sn-Pb-Ag low-melting brazing material is about 3 kg/mm², while the material solid-phase diffusion-bonded in accordance with this invention has about twice the strength, the values being around 6 kg/mm². As for the temperature dependence, the bond strength under shear of the material using the Sn-Pb-Ag low-melting brazing material becomes zero in the vicinity of 180 °C which is the melting point of the brazing material itself. The solid-phase diffusion-bonded material of this invention, by contrast, exhibits a bond strength under shear of 3 kg/mm² or more above 200 °C and retains a strength of 2 kg/mm² even above 250 °C. FIG. 4 is a micrograph of a cross section illustrating the bond interfaces and neighboring portions of a laminate composed of an Al-1%Si-0.5%Cu target, Ag foil, and OFC backing plate according to the present invention.

(Example 2)

Targets were made by solid-phase diffusion bonding in the same manner as described in Example 1 with the exception that inserts of copper foil or nickel foil were used instead. Similar effects were achieved.

(Example 3)

A Ti target material in the form of a disk 300 mm in diameter and an oxygen-free copper (OFC) backing plate of the same size were ultrasonically degreased and rinsed with acetone. An insert of Ag foil 100 µ m thick was used. The insert, after the ultrasonic degreasing and rinsing with acetone, was sandwiched between the Ti target material and the OFC backing plate.

The laminate consisting of the Ti target material, Ag foil insert, and OFC backing plate was diffusion-bonded in a vacuum of 5×10^{-4} Torr, at a bonding temperature of 250 °C, and under a load of 8 kg/mm².

Similarly in Example 1, the bond strength values under shear at room temperature of test pieces cut out of five different diametral points of the diffusion-bonded material are compared with those of corresponding test pieces of a laminate consisting of the same Ti target material and OFC backing plate similarly bonded but with an ordinary low-melting brazing material of the Sn-Pb-Ag system. A similar graph as in FIG. 2 was btained. The temperature dependence

of the bond strength values under shear of these bonded materials was similar as in FIG. 3. The bond strength under shear of the laminate using the Sn-Pb-Ag low-melting brazing material is about 3 kg/mm², while the material solid-phase diffusion-bonded in accordance with this invention has about twice the strength, the values being around 6 kg/mm². As for the temperature dependence, the bond strength under shear of the material using the Sn-Pb-Ag low-melting brazing material becomes zero in the vicinity of 180 °C which is the melting point of the brazing material itself. The solid-phase diffusion-bonded material of this invention, by contrast, exhibits a bond strength under shear of 3 kg/mm² or more above 200 °C and retains a strength of 2 kg/mm² even at 250 °C.

(Example 4)

A tungsten target material of high purity (>99.999%) in the form of a disk 295 mm in diameter was diffusion-bonded to a titanium backing plate of industrial purity through an Ag insert in a vacuum of 5 x 10^{-4} Torr, at a bonding temperature of 400° C, and under a load of 8 kg/mm². A micrograph of a cross section illustrating the bond interfaces of the bonded material thus obtained is shown in FIG. 5. It can be seen from the photograph that interfaces having the bonded area percentage of 100% with non-bonded portions such as pores were obtained. The bond strength under shear at room temperature of test pieces cut out from five diametral points in the manner described in Example 3 was 7 kg/mm². On the other hand, the bond strength under shear of test pieces of a material bonded using an In brazing material was at a level of as lower as of 1 kg/mm². This difference verifies the superiority of solid-phase diffusion bonding.

(Example 5)

Targets were made by solid-phase diffusion bonding similarly to Example 3 but using inserts of copper foil or nickel foil. Similar effects were attained.

(Example 6)

A high-purity (>99.999%) titanium target in the form of a disk 295 mm in diameter was diffusion-bonded to a titanium backing plate of industrial purity directly without the use of an insert under a vacuum of 5 x 10^{-5} Torr and at a bonding temperature of 550 °C, load of 7.5 kg/mm², and strain rate of 2x 10^{-5}/sec. In FIG. 6 are compared the bond strength under shear at room temperature of an assembly made by solid-phase diffusion bonding in accordance with this invention with that of a assembly which used an In brazing material. A micrograph of the bond interface of the bonded assembly is shown in FIG. 7. The crystal grain size of the target after bonding was 50 µm. The photograph clearly indicates that the interface had attained 100% bonding without non-bonded portions such as pores. The test piece at room temperature exhibited a bond strength under shear of 25 kg/mm² and a tensile strength under shear of 43 kg/mm². The In brazing material-bonded piece gave a bond strength under shear at a low level of 1 kg/mm². This testifies to the superiority of solid-phase diffusion bonding.

(Example 7)

A target assembly was made by solid-phase diffusion bonding in the same manner as described in Example 6 with the exception that the bonding temperature was changed to 500 °C and the strain rate to 1 x 10^{-5}/sec. Similar effects were achieved.

[Advantages of the invention]

Solid-phase diffusion bonding at a low temperature and pressure has the following features:

(1) The uniformity of crystal structure is maintained with the suppression of crystal grain growth.

(2) The process of fabrication causes no damage to the target material.

(3) Interdiffusion of the atoms constituting the target material, backing plate, and insert if used across the bond interfaces produces high degrees of adhesion and bond strength.

(4) The sharp drop of bond strength is avoided as found in the rise of the service temperature that can occur with a low-melting brazing material.

(5) Solid-phase bonding gives reliable bonds of a bonding area percentage of 100% without non-bonded portions such as pores that can result from ordinary bonding, due to shrinkage on solidification of a brazing material.

Consequently, this invention offers advantages as follows:

(a) A target material can be bonded to a backing plate without the possible danger of being damaged ; (b) uniformity of sputtering is ensured with the result that the film thickness is kept constant and the film properties are made uniform and stable; (c) a greater electric power can be put for sputtering, and therefore the throughput for film forming by sputtering can be improved; and (d) the target itself can be baked at around 200 °C, thus reducing adsorbed water, gas, and the like in the target surface.

Claims

1) A sputtering target assembly comprising a sputtering target and a backing plate characterized in that said sputtering target and backing plate are solid-phase diffusion-bonded with or without an insert or

inserts interposed therebetween so as to have solid phase diffusion-bonded interfaces, said diffusion-bonded sputtering target substantially maintaining metallurgical characteristics and properties that the sputtering target had before it is diffusion-bonded to said backing plate.

2) A solid-phase diffusion-bonded sputtering target assembly characterized being composed of a target material having a melting point below 1000 °C, one or more insert and a backing plate, said target material, said insert and said backing plate having solid-phase diffusion bonding interfaces formed therebetween, said target material having uniform crystal structure with a grain size not exceeding 250 µm.

3) A sputtering target assembly according to claim 1 in which said target material consists of aluminum or an aluminum alloy.

4) A sputtering target assembly according to claim 2 in which said insert consists of silver or a silver alloy, copper or a copper alloy, or nickel or a nickel alloy.

5) A sputtering target assembly according to claim 3 in which said insert consists of silver or a silver alloy, copper or a copper alloy, or nickel or a nickel alloy.

6) A method of manufacturing a sputtering target assembly characterized by solid-phase diffusion bonding of a target material of a given final shape having a melting point below 1000 °C and a backing plate of a given final shape, with one or more insert interposed therebetween, under a vacuum at a temperature between 150 and 300 °C, said target material having a uniform crystal structure with a grain size not exceeding 250 µm.

7) A solid-phase diffusion-bonded sputtering target assembly characterized by being composed of a target material having a melting point no less than 1000 °C, one or more insert selected from the group consisting of metals or alloys having lower melting points than the target material, and a backing plate, said target material, said insert and said backing plate having solid-phase diffusion bonded interfaces formed therebetween.

8) A sputtering target assembly according to the claim in which said target material is a refractory metal selected from the group consisting of W, Mo, Ti, Ta, Zr and Nb.

9) A sputtering target assembly according to claim 7 in which said insert consists of silver or a silver alloy, copper or a copper alloy, or nickel or a nickel alloy.

10) A sputtering target assembly according to claim 8 in which said insert consists of silver or a silver alloy, copper or a copper alloy, or nickel or a nickel alloy.

11) A method of manufacturing a sputtering target assembly characterized by solid-phase diffusion bonding of a target material of a given final shape having a melting point not less than 1000 °C and a backing plate of a given final shape, with an insert or inserts interposed therebetween, said insert(s) being made of one or more materials selected from the group consisting of metals or alloys having lower melting points than the target material, under a vacuum at a temperature between 200 and 600 °C and at a pressure between 0.1 and 20 kg/mm².

12) A solid-phase diffusion-bonded sputtering target assembly characterized by being composed of a titanium target material and a backing plate of titanium, which have solid-phase diffusion bonding interfaces formed therebetween, said target material having a uniform crystal structure with a crystal grain size not exceeding 100 µm.

13) A method of manufacturing a solid-phase diffusion-bonded sputtering target assembly composed of a titanium target material and a backing plate of titanium in which the target material has uniform crystal structure with a crystal grain diameter not exceeding 100µm, characterized by solid-phase diffusion bonding of a titanium target material and a backing plate of titanium under conditions such that the strain rate attained is no more than 1×10^{-3}/sec.

14) A method according to claim 13 in which the diffusion bonding is performed at a temperature between 350 and 850 °C.

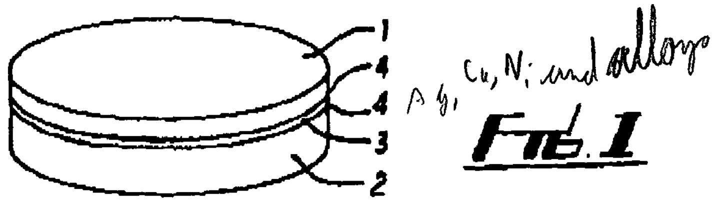
1
4
4
3
2
Ag, Cu, Ni and alloys

FIG. 1

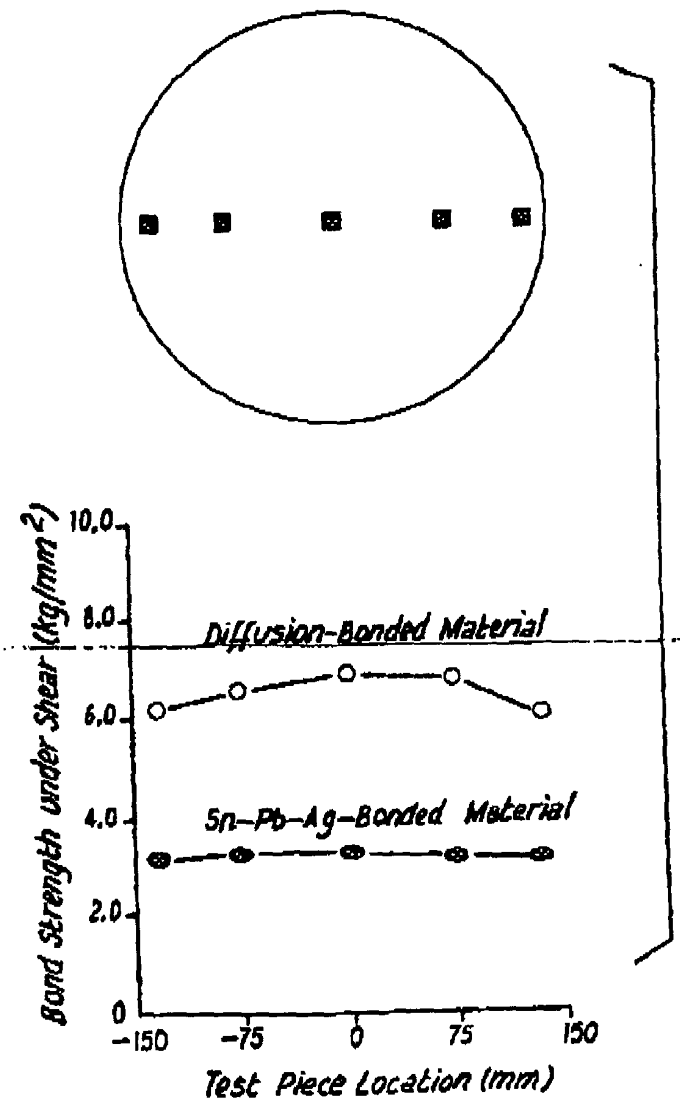
Bond Strength under Shear (kg/mm²)
10.0
8.0
6.0
4.0
2.0
0
Diffusion-Bonded Material
Sn-Pb-Ag-Bonded Material
-150
-75
0
75
150
Test Piece Location (mm)

FIG. 2

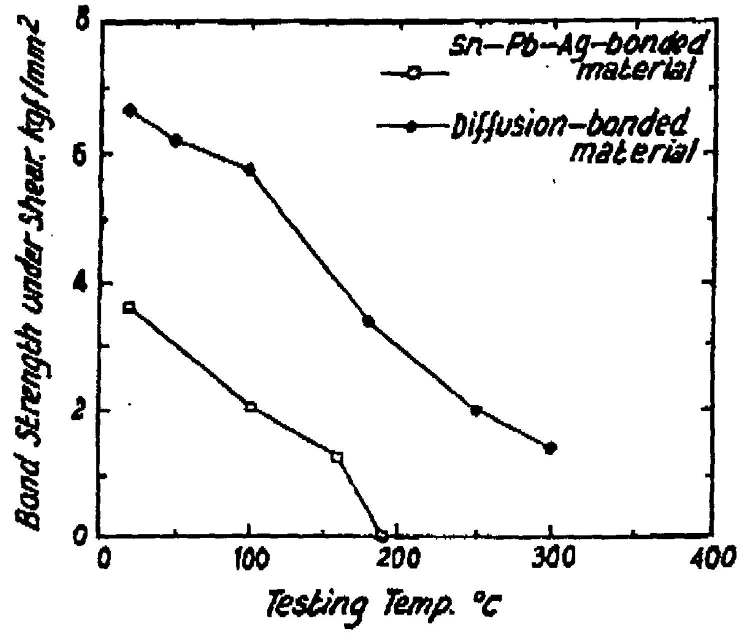
Sn–Pb–Ag-bonded material
Diffusion-bonded material
Bond Strength under Shear, kgf/mm2
Testing Temp. °C
0
2
4
6
8
0
100
200
300
400

FIG.3

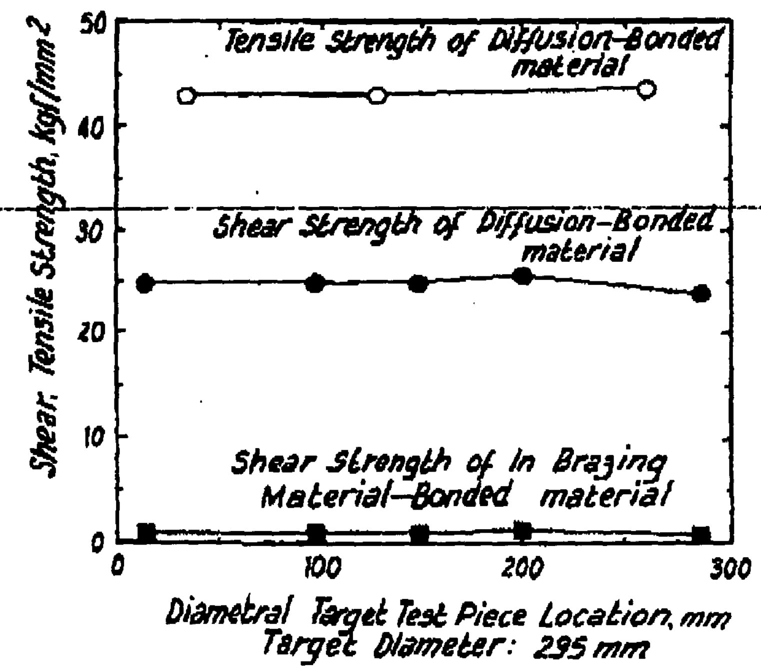
Tensile Strength of Diffusion-Bonded material
Shear Strength of Diffusion-Bonded material
Shear Strength of In Brazing Material-Bonded material
Shear, Tensile Strength, kgf/mm2
Diametral Target Test Piece Location, mm
Target Diameter: 295 mm
0
10
20
30
40
50
0
100
200
300

FIG.6


Al
Ag
Cu

FIG. 4

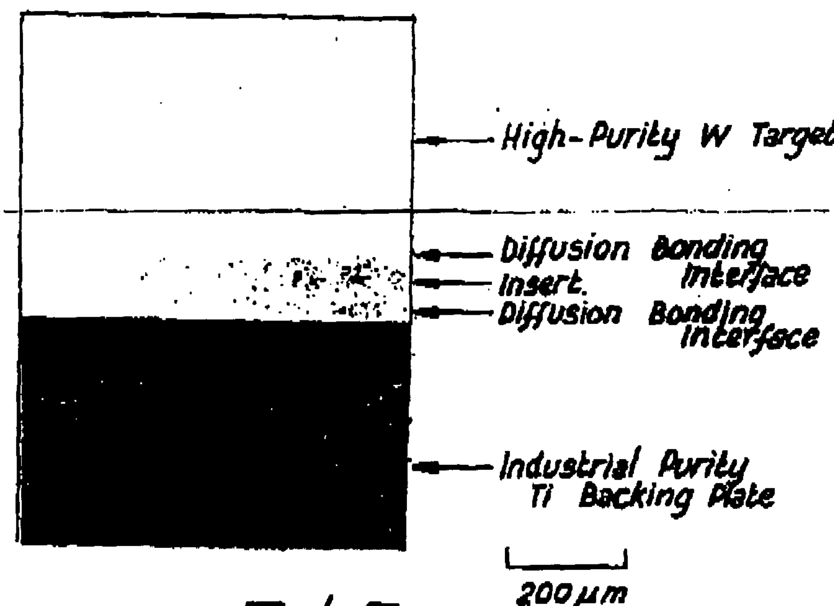
High-Purity W Target
Diffusion Bonding Interface
Insert.
Diffusion Bonding Interface
Industrial Purity Ti Backing Plate
200μm

FIG. 5

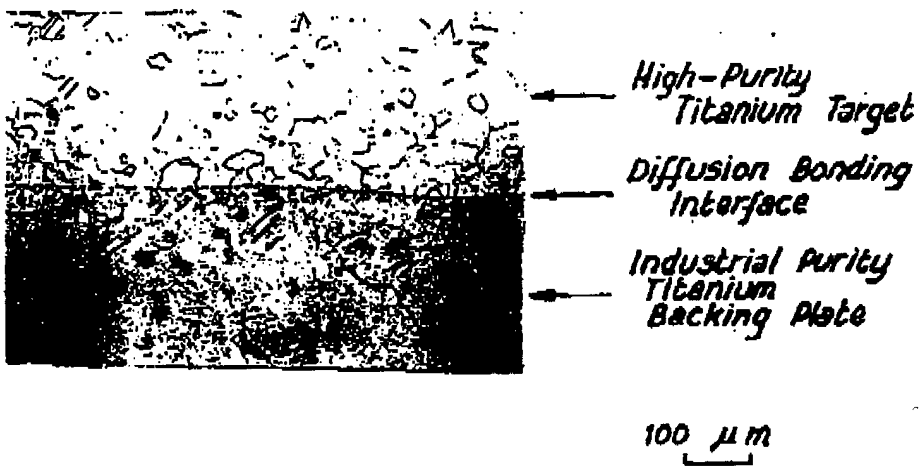
High-Purity Titanium Target
Diffusion Bonding Interface
Industrial Purity Titanium Backing Plate
100 µm

FIG. 7

European Patent Office

EUROPEAN SEARCH REPORT

Application Number EP 93307621.8

Category	DOCUMENTS CONSIDERED TO BE RELEVANT — Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
D,A	PATENT ABSTRACTS OF JAPAN, unexamined applications, C section, vol. 16, no. 419, September 03, 1992 THE PATENT OFFICE JAPANESE GOVERNMENT page 38 C 981 * No. 04-143 268 (FUJITSU LTD) * --	1-14	C 23 C 14/34
D,A	PATENT ABSTRACTS OF JAPAN, unexamined applications, C section, vol. 16, no. 419, September 03, 1992 THE PATENT OFFICE JAPANESE GOVERNMENT page 38 C 981 * No. 04-143 269 (FUJITSU LTD) * --	1-14	
A	EP - A - 0 342 894 (KABUSHIKI KAISHA TOSHIBA) * Claims * ----	1-14	TECHNICAL FIELDS SEARCHED (Int. Cl.5) C 23 C 14/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	03-01-1994	HOFBAUER

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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